PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P27839PC00	**FOR FURTHER ACTION** See Form PCT/IPEA/416	
International application No. PCT/IB2004/052653	International filing date *(day/month/year)* 03.12.2004	Priority date *(day/month/year)* 05.12.2003
International Patent Classification (IPC) or national classification and IPC G01N17/00		
Applicant UNIVERSITY OF PRETORIA et al.		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 7 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 15 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☒ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

☒	Box No. I	Basis of the opinion
☐	Box No. II	Priority
☒	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
☐	Box No. IV	Lack of unity of invention
☒	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
☐	Box No. VI	Certain documents cited
☒	Box No. VII	Certain defects in the international application
☒	Box No. VIII	Certain observations on the international application

Date of submission of the demand 04.10.2005	Date of completion of this report 03.03.2006
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Filipas, A Telephone No. +49 89 2399-2255

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/IB2004/052653

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:

   ☐ international search (under Rules 12.3 and 23.1(b))
   ☐ publication of the international application (under Rule 12.4)
   ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1-11 filed with telefax on 12.10.2005

Claims, Numbers

1-12 filed with telefax on 12.10.2005

Drawings, Sheets

1/2, 2/2 as originally filed

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☒ The amendments have resulted in the cancellation of:
   ☐ the description, pages
   ☒ the claims, Nos. 13
   ☐ the drawings, sheets/figs
   ☐ the sequence listing *(specify)*:
   ☐ any table(s) related to sequence listing *(specify)*:

4. ☒ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   ☐ the description, pages
   ☒ the claims, Nos. 1,8
   ☐ the drawings, sheets/figs
   ☐ the sequence listing *(specify)*:
   ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

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Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application,

☒ claims Nos. 11,12

because:

☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (specify):

☐ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. are so unclear that no meaningful opinion could be formed *(specify)*:

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☒ no international search report has been established for the said claims Nos. 11,12

☐ the nucleotide and/or amino acid sequence listing does not comply with the standard provided for in Annex C of the Administrative Instructions in that:

the written form	☐	has not been furnished
	☐	does not comply with the standard
the computer readable form	☐	has not been furnished
	☐	does not comply with the standard

☐ the tables related to the nucleotide and/or amino acid sequence listing, if in computer readable form only, do not comply with the technical requirements provided for in Annex C-*bis* of the Administrative Instructions.

☒ See separate sheet for further details

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

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Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-10
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-10
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-10
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item I

The amendments filed with telefax on 12.10.2005 introduce subject-matter which extends beyond the content of the application as filed, contrary to Article 34(2)(b) PCT. The amendments concerned are the following:

Claim 1: "... a member ... for ... **rotating relative** to a body of liquid, with **at least** a portion of the surface being submerged in the liquid **during rotation** ..."

Claim 8: "... continuously **rotating** the member ... **at least partially** submerging the said surface ... **at least** a portion of the surface is submerged ..."

On the one hand, the original application does not broadly refer to a member rotating relative to a body of liquid, but to a specific embodiment comprising a housing and a disk, as defined in original claim 2 (see also the objection under section VIII below).
It should be noted that when amendments are based on particular embodiments presented in the description, they should include all the features described with respect to such embodiments and cannot be limited only to some of said features.

On the other hand, the original application refers to the feature of partially submerging the surface, but not to the feature of **at least** partially submerging the surface.

Re Item III

Present claims 11 and 12 are identical with claims 12 and 13, respectively, of the application as originally filed, and the International Search Report has not been established in respect of said claims 12 and 13 because they only contain references to the description and the drawings and thus leave unclear which technical features are intended to be protected (see also Rule 6.2(a) PCT).

Re Item V

1. Reference is made to the following documents:

D1: US-A-5 155 555 (WETEGROVE et al.) 13 October 1992 - *cited in the application*
D2: US-A-5 796 478 (WETEGROVE) 18 August 1998

2. Both D1 and D2 disclose (see in particular the passages indicated in the International Search Report) an apparatus and a corresponding method from which the subject-matter of claims 1 and 8, insofar as it can be understood (see the objection under section VIII below), differs in that both the rotation of the member providing the surface on which the monitored biofilm is formed, and the measurement of biofilm formation on a measuring zone of said surface are performed continuously.

According to D1 and D2, said rotation and measurement are performed intermittently: a portion of the surface on which the monitored biofilm is formed is immersed into a fluid stream, where it remains for a predetermined amount of time, and then it is rotated so that it is disposed outside said fluid stream, where biofilm formation is measured.

The subject-matter of independent claims 1 and 8 of the present application appears therefore to be new (Article 33(2) PCT).

The intermittent rotation of the surface on which the monitored biofilm is formed, which is taught by D1 and D2, may cause some of the biofilm to fall from the portion of said surface which moves out of the fluid stream for measurement, so that the actual biofilm formation is not accurately measured.
The problem to be solved by the present invention may be regarded as increasing measurement accuracy.
The solution to this problem proposed in claims 1 and 8 of the present application appears to involve an inventive step (Article 33(3) PCT), since none of the available prior art discloses or hints at the solution according to the invention - the continuous rotation of the surface on which the monitored biofilm is formed (requiring also a corresponding continuous measurement) reduces the tendency of the biofilm to fall from the rotated surface when moving out from the fluid stream.

3. Claims 2-7, 9 and 10 are dependent on claims 1 and 8, respectively, and as such also appear to meet the requirements of the PCT with respect to novelty and inventive step.

4. Claims 1-10 appear to satisfy the criterion of industrial applicability (Article 33(4) PCT), since the claimed invention can be used for measuring the formation of biofilm on a surface.

Re Item VII

1. Independent claims 1 and 8 are not in the two-part form in accordance with Rule 6.3(b) PCT, with those features known in combination from the prior art being placed in the preamble and with the remaining features being included in the characterising part.

2. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

Re Item VIII

Claims 1 and 8 broadly refer to a member providing the surface on which the monitored biofilm is formed.
However, the description and drawings only refer to a disk arranged according to claim 2, and no alternative members are envisaged.

Hence, claims 1 and 8 are not supported by the description as required by Article 6 PCT.

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METHOD AND APPARATUS FOR MONITORING BIOFILM FORMATION

INTRODUCTION

This invention relates to a method and apparatus for monitoring biofilm formation.

BACKGROUND TO THE INVENTION

In this specification, the term "biofilm" means microorganisms accumulated or formed on a surface. The impact of biofilm formation varies in different technical systems, thus, they can tolerate biofilms to a lesser or greater extent until an interference of process or product quality is observed. In order to keep biofilm growth below a certain "threshold of interference", it is necessary to obtain information about the actual extent of biofilm formation for timely and effective countermeasures. Such a "threshold of interference" varies according to the demands of a given process. Known monitoring devices for monitoring biofilm formation on surfaces include fibre optic devices and infrared monitors. (*Melo, L. F., Flemming, H-C., Cloete, T. E. (2003), IWA Publishing. "Water Science & Technology, Biofilm Monitoring" pp1-8, 19-24, 39-43.*)

A known fibre optic device consists of a sending fibre and a receiving fibre, both penetrating a wall of a water pipe with the tips of the fibres even to the inner pipe surface. By using the intensity of backscattered light for assessing the thickness of the deposit, which has accumulated on the tip of the fibre, biofilm

formation on the tips of the fibres is detected. The receiving fibre collects the signal and forwards it to a detection and quantification unit. A disadvantage of this device is that, since the tips of the optical fibres are relatively very small, there is only a small surface on which biofilm accumulates. The measurements taken are therefore not representative of biofilm formation in a complete system.

A known infrared monitor used for detecting biofilm formation on a surface in a flowing system, includes a pipe through which water flows. The pipe has transparent glass walls, which provide the surface for biofilm accumulation. An infrared transmitter is located on one side of the pipe and an infrared receiver is located on an opposite side. Radiation from the transmitter to the receiver passes through both glass walls of the pipe; the biofilm accumulated on the glass surface; and the water passing through the pipe. The difference between the radiation emitted and that received is the amount absorbed by the system. The amount of infrared radiation absorbed by the biofilm is proportional to the amount of biofilm present on the surface.

A disadvantage of this system is that the difference between the radiation emitted and that received is the amount of radiation absorbed by the system and not only radiation absorbed by the biofilm formed on the surface. Thus, as properties of the water varies, the amount of radiation absorbed by the water

also varies and therefore does not produce accurate results regarding the amount of biofilm formation.

US patent number 5,155,555 discloses a method and apparatus for measuring biofilm formation in an opaque process stream. A section of a disk is immersed into the fluid stream and remains in the stream for a predetermined amount of time to allow biofilm to accumulate on the surface of the disk. After the predetermined amount of time, the disk is rotated to a position so that the previously immersed section is exposed for optical monitoring. The monitoring takes place by casting a light beam of known intensity *i* onto the biofilm formed on the disk and measuring the intensity *i'* of the light reflected from the disk. The two intensities *i* and *i'* are then compared and the ration is a measure of film thickness.

A disadvantage of the above method and apparatus for measuring biofilm formation is that since the disk remains in the stream for a predetermined amount of time and is then removed from the stream to take the measurements, the measurements are relatively inaccurate. By retaining the disk in a static position in the stream during formation of biofilm on the surface of the disk and thereafter moving the disk out of the stream, some of the biofilm may fall off from the disk or it may not form uniformly, thus not providing accurate measurements.

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A second disadvantage is that the measurements are not taken continuously but at predetermined intermittent times and the apparatus therefore does not provide real time measurement of biofilm formation to allow continuous control over biofilm formation. It is known that it is relatively more effective to prevent the formation of biofilm, or to remove such biofilm shortly after the formation thereof, than to remove the biofilm after a period of growth, as the biofilm develops a protective layer which is resistant to biocides.

OBJECT OF THE INVENTION

It is therefore an object of the present invention to provide a method and apparatus for monitoring biofilm formation with which the aforesaid disadvantages can be overcome or at least minimised.

SUMMARY OF THE INVENTION

According to a first aspect of the invention there is provided apparatus for continuously monitoring biofilm formation on a surface comprising:

- a member providing said surface for continuously rotating relative to a body of liquid, with at least a portion of the surface being submerged in the liquid during rotation and with another portion of the surface being disposed outside the body of liquid and providing a measuring zone; and

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- a sensor for being located outside the body of liquid and for continuously measuring biofilm formation on the measuring zone of the surface.

The apparatus may include a housing.

The member may be in the form of a disk disposed inside the housing and may be rotatable about an axis of rotation extending perpendicularly through the plane in which the disk extend.

The housing may be provided with a liquid inlet and a liquid outlet and a passage for the liquid extending through the housing from the inlet to the outlet, with at least a portion of the disk being disposed inside the passage.

The liquid may fill the housing only partly.

Further according to the invention, a plurality of vanes are mounted along the outer periphery of the disk and may extend from the disk to aid rotation of the disk about its central axis, whilst the liquid flows from the inlet to the outlet along the passage.

The sensor may be disposed inside the housing above the level of the liquid, in use.

The sensor may include a transmitter for transmitting a light beam onto said measuring zone and a receiver for receiving light reflected from the surface.

Alternatively, the disk may be transparent and the transmitter and the receiver may be located on opposite sides of the disk, the arrangement being such that the transmitter transmits a light beam onto said measuring zone and the receiver receives the light passing through the surface.

Further according to the invention, a plurality of bodies of different material are mounted on the disk in the measuring zone for observing biofilm formation on different materials.

According to a second aspect of the invention there is provided a method for continuously monitoring biofilm formation on a surface including the steps of:

- providing a body of liquid;
- providing a member defining a surface;
- continuously rotating the member;
- at least partially submerging the said surface in the body of liquid such that, during rotation, at least a portion of the surface is submerged in the liquid and such that the surface defines a measuring zone which is disposed outside the body of liquid;

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- providing a sensor disposed outside the body of liquid and for continuously measuring biofilm formation on the surface; and
- continuously measuring biofilm formation by measuring light being received from the said measuring zone of the surface with the sensor.

The method may include the further step of observing biofilm formation on different types of materials.

The step of observing biofilm formation on different types of materials may include the steps of providing bodies of different types of materials, mounting the bodies on the member in the measuring zone so that they are rotated with the member and observing said biofilm accumulation thereon

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described further by way of a non-limiting example with reference to the accompanying drawings wherein:

figure 1 is a perspective view of an apparatus according to a preferred embodiment of the invention for monitoring biofilm formation, with a housing being open to show a member providing a surface on which the biofilm forms; and

figure 2 is the same as figure 1 with the housing closed and showing a sensor for monitoring the biofilm formation on the surface.

DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

Referring to the drawings, an apparatus for monitoring biofilm formation according to a preferred embodiment of the invention is generally designated by reference numeral 10.

The apparatus 10 for monitoring biofilm formation on a surface 12 comprises a disk-shaped member 14 which provides said surface 12; and a sensor 16 for measuring biofilm formation on a measuring zone 18 of the surface 12.

A plurality of vanes 20, are mounted along and extend from the outer periphery of the disk-shaped member 14.

The apparatus 10 includes a housing 22 wherein the member 14 is located. A body of liquid 24, such as water, is disposed inside the housing 22 and fills the housing 22 only partly. The housing 22 has a liquid inlet 26 and a liquid outlet 28 and a passage for the liquid extending through the housing 22 from the inlet 26 to the outlet 28. The apparatus further includes bodies 29 of different material mounted on the member 14 in the measuring zone 18 so that they are rotated with the member. The bodies 29 make it possible to observe biofilm formation on different materials.

In use, the member 14 is continuously moved into and out of the liquid 24 by being rotated about its central axis 30. At any given time, a portion of the member 14 is therefore submerged in the liquid 24 and another portion, providing the said measuring zone 18, is disposed outside the liquid 24.

Rotation of the member 14 is further facilitated by a water pump 32, which pumps the liquid 24 into the housing 22; and the vanes 20 extending from the member 14 aiding in propulsion thereof whilst the liquid 24 flows from the inlet 26 to the outlet 28 along the passage.

The sensor 16 is located inside the housing 22 above the level of the liquid 24. The sensor 16 includes a transmitter and a receiver (both not shown). The transmitter transmits green light onto the surface 12 as it was found that the most accurate results were obtained when using green light, in comparison with light of other wavelengths that were tested.

Further in use, as liquid 24 is pumped into the housing 22 via the inlet 26, through the passage and out of the housing 22 via the outlet 28, the member 14 is rotated about its central axis 30 as shown by arrow A in figure 1. Rotation of the member 14 continuously moves the member 14 into and out of the liquid 24, the arrangement being such that biofilm formation on the surface 12 can be measured at the measuring zone 18. The transmitter transmits a green light beam onto said measuring zone 18 and the receiver receives the beam of light

being reflected from the surface 12. The sensor 16 sends a signal, which represents the amount of reflected light to a processor (not shown) for determining the amount of biofilm formation on the surface 12, the amount of reflected light being proportional to the amount of biofilm formed on the surface 12. Biofilm also forms on the bodies 29 of different material. Biofilm accumulation on different materials can therefore also be observed.

It will be appreciated that the apparatus 10 provides real time monitoring of biofilm formation on the surface 12 since the member 14 continuously rotates into and out of the liquid 24. It will further be appreciated that biofilm formation on different materials can be observed by using bodies 29 of different materials and intermittently removing said bodies 29 to monitor biofilm accumulation thereon. The apparatus 10 can be connected to an existing system and as the liquid 24 continuously passes through the apparatus 10, accurate measurements of biofilm formation, representing the entire system, is obtained. The apparatus 10 according to the invention could therefore provide an output signal to a biocide dosing means (not shown) for applying an effective amount of biocide to the water 24 as soon as measurements indicate that biofilm has formed on the surface 12.

It will also be appreciated that variations in detail are possible with a method and apparatus for monitoring biofilm formation according to the invention without departing from the scope of this disclosure. For example, the disk may

be transparent and the transmitter and the receiver may be located on opposite sides of the disk, the arrangement being such that the transmitter transmits a light beam onto said measuring zone and the receiver receives the light passing through the surface. The received light is proportional to the amount of biofilm formed on the surface. Further for example, the side walls of the housing 20 could be either transparent or opaque to measure the formation of different types of microorganisms.

CLAIMS

1. Apparatus for continuously monitoring biofilm formation on a surface comprising:

   - a member providing said surface for continuously rotating relative to a body of liquid, with at least a portion of the surface being submerged in the liquid during rotation and with another portion of the surface being disposed outside the body of liquid and providing a measuring zone; and
   - a sensor for being located outside the body of liquid and for continuously measuring biofilm formation on the measuring zone of the surface.

2. Apparatus according to claim 1 including a housing with the member being in the form of a disk disposed inside the housing and rotatable about an axis of rotation extending perpendicularly through the plane in which the disk extends, and wherein the housing is provided with a liquid inlet and a liquid outlet and a passage for the liquid extending through the housing from the inlet to the outlet, with at least a portion of the disk being disposed inside the passage, and wherein the liquid fills the housing only partly.

3. Apparatus according to claim 2 including a plurality of vanes mounted along the outer periphery of the disk and which extend from the disk to aid rotation of the disk about its central axis, whilst the liquid flows from the inlet to the outlet along the passage.

4. Apparatus according to claim 2 or claim 3 wherein the sensor is disposed inside the housing above the level of the liquid, in use.

5. Apparatus according to any one of the preceding claims wherein the sensor includes a transmitter for transmitting a light beam onto said measuring zone and a receiver for receiving light reflected from the surface.

6. Apparatus according to any one of claims 1 to 4 wherein the disk is transparent and the transmitter and the receiver are located on opposite sides of the disk, the arrangement being such that the transmitter transmits a light beam onto said measuring zone and the receiver receives the light passing through the surface.

7. Apparatus according to any one of claims 2 to 6 wherein a plurality of bodies of different material are mounted on the disk in the measuring zone for observing biofilm formation on different materials.

8. A method for continuously monitoring biofilm formation on a surface including the steps of:

- providing a body of liquid;
- providing a member defining a surface;
- continuously rotating the member;
- at least partially submerging the said surface in the body of liquid such that, during rotation, at least a portion of the surface is submerged in the liquid and such that the surface defines a measuring zone which is disposed outside the body of liquid;
- providing a sensor disposed outside the body of liquid and for continuously measuring biofilm formation on the surface; and
- continuously measuring biofilm formation by measuring light being received from the said measuring zone of the surface with the sensor.

9. A method for monitoring biofilm formation according to claim 8 which includes the further step of observing biofilm formation on different types of materials.

10. A method for monitoring biofilm formation according to claim 9 wherein the step of observing biofilm formation on different types of materials

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includes the steps of providing bodies of different types of materials, mounting the bodies on the member in the measuring zone so that they are rotated with the member and observing said biofilm accumulation thereon.

11. Apparatus substantially as herein described and illustrated in the accompanying drawings.

12. A method for monitoring biofilm formation substantially as herein described and exemplified.